Junk Yard Wars, Monster Garage and Student Projects

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Abstract

There are many similarities between student projects and the popular television shows Junk Yard Wars and Monster Garage. The "figure it out as you go" approach used on these television shows, although entertaining, is not the "figure it out in advance" approach followed by design engineers in industry. Although engineering educators provide instruction on the engineering design process, students with limited experience will often forget their classroom instruction, and fall back to the Junk Yard Wars process. This paper discusses the similarities between these popular shows and the constraints placed on students projects. It also discusses methods that can be used to encourage, motivate, and in some cases force students to put more emphasis on the engineering side of their projects. It also discusses aspects of engineering-society-sponsored projects that make some more conducive to the engineering process than others.

Introduction

Junk Yard Wars and Monster Garage are popular television shows in which teams are challenged to make a device within a short period of time. The projects rely on the mechanical creativity of the team members, are heavy on integration (finding something and making it work), employ little if any analysis, and communicate the design using a very crude sketch. The teams must quickly figure out what they need to do, find the materials, modify or adapt parts and assemble them, overcome unforeseen obstacles, and compete the device against those developed by other teams. In virtually all cases, the projects are heavy on the fabrication side and light on the engineering side. The most common fabrication processes used on the shows are oxyacetylene torches and welders. In many cases, the team members don't know if their device will actually work until it is completed and they test it for the first time during the competition. There are frequent mechanical failures and surprises during the competitions. These shows are popular with engineering students, are entertaining, and contain demonstrations on fabrication methods. These demonstrations have significant educational value to someone with no exposure to the methods being used.

There are many similarities between the projects undertaken on Junk Yard Wars, Monster Garage and student projects. In all cases, the teams must work under severe time constraints, be creative, work with limited materials or budgets, and fabricate a device that is used in a competition. All of these are real world constraints and provide students with practical experience. However, in many cases students have a tendency to follow the Junk Yard Wars development process – the figure it out while it is being fabricated approach. This is not the approach that engineers in industry follow. It is also not the approach taught in engineering design courses. The purpose of this paper is to highlight the similarities between these popular shows and unsuccessful student projects, and to suggest ways in which student projects can have a higher probability of success.

Good Engineering Practice

In industry, engineers also apply their creative abilities during design. However, in addition to creativity, they are much more disciplined in their planning, design, verification, and testing. The detailed information contained in even the simplest design is substantial and often goes through several iterations to satisfy competing requirements and objectives. Extensive assembly and detailed part drawings are the result of much iteration and attention to

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detail. Quite simply put, engineers generally try to figure things out in advance so that everything works as intended. This is necessary to protect the public, their employer, and the reputation of the profession. This disciplined design approach is quite different than the Junk Yard Wars development process.

There are many textbooks and technical papers that address the subject of design [Dhillon, 1], [Dym, 2], [Ertas, 3], Hyman, 4], and Ullman,5]. Each contains recommended steps to be followed during the design process, and all engineering students study one of these design processes at some point in their education. Design in its simplest form is the process of figuring out how to make something that meets a set of requirements. Design by its very nature is iterative and many a project has ended up being unsuccessful because planners assume that everything will go right the first time.

A process for developing a product is shown in Figure 1. This high-level process description is intentionally simple and does not attempt to include the myriad of things that could be included. It is believed by the author to be a close reflection of what is generally considered to be good engineering practice. Note that the arrows point both upward and downward. This is in recognition that design by its very nature is iterative. This iteration is in large part due to the fact that people learn during the design process as they resolve problems that were not foreseen at the onset. An experienced design team will generally be able to avoid many problems based on lessons learned from previous projects. However, even experienced design teams have to iterate as they progress through the design process.

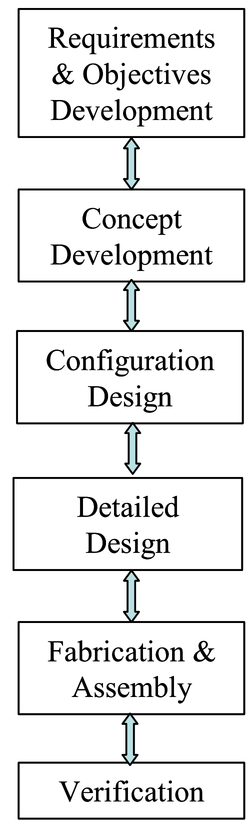

Figure 1. Steps in Design Process

Table 1 compares activities performed in the typical Junk Yard Wars approach with good engineering design practice. Note that the two primary steps that are left out are Configuration Design and Detail Design. It is during these two important phases that engineers spend most of their time gathering information and figuring out how to make sure that all requirements are met, achieve objectives in an optimal manner, and assure that individual parts fit together and function as a system. Analyses and tests are also performed during these steps to verify performance requirements are achieved. Analyses and tests are ideally done during the Configuration Design step. In practice, analyses and tests often are not completed prior to the start of drawing production. If problems are identified, iteration and rework is required.

Information gathering is an often very time consuming activity performed by engineers throughout the entire design process. This involves searching for parts that can be integrated into a specific design, holding discussions with potential vendors, etc. An experienced engineer can save a design team significant amounts time due to familiarity with vendors and products gained over many years. In a Junk Yard Wars program the participants spend a significant amount of their allotted time looking for material that can be modified to fabricate their device. In this respect, there are similarities between engineers and participants in Junk Yard Wars. Each is gathering information and making decisions on whether a potential item will be acceptable.

Table 1: Comparison of Junk Yard Wars and Engineering Practice

Design Process Steps	Junk Yard Wars	Engineering Practice
Requirements	General description of what must be accomplished	List of mathematical constraints that must be satisfied.
Objectives	Given little attention by participants	Attributes that the design team or customer would like to accomplish.
Concepts	Sketches created on white board, some iteration by participants	Sketches and preliminary layouts, proof of concept analyses and tests, multiple concepts with an optimal concept selected based on objectives
Configuration Design	None	Assembly models & part models developed using modern CAD tools, fit and function, performance verified through analyses or tests
Detail Design	None	Assembly and part drawings, specifications for purchased parts or materials
Fabrication	Cutting and welding processes used to modify junk to accomplish requirements.	Broad range of methods depending on production volume and cost
Verification	Tested during competition	Comprehensive testing prior to release or final production

Providing Motivation for Good Engineering Practice

Since students have a natural tendency to apply the Junk Yard Wars design approach to projects that involve hardware fabrication, how can faculty motivate them to follow good engineering practice? The following sections discuss several methods employed by the author or other faculty members to answer this question.

Senior Engineering Students Need Supervision

One of the objectives of senior projects is to provide students with the opportunity to complete a significant and open-ended engineering problem. There are many ways in which faculty can interact with students while meeting this objective. One way would be to explain the overall project goals and requirements to the students and then let them work totally independently. There are merits to this approach, but the author believes that this totally hands-off approach leads to adoption of the Junk Yard Wars approach by the students.

Students or practicing engineers facing a new project assignment for the first time are often overwhelmed with the number of things that have to be accomplished in such a short amount of time. Although senior level students have been exposed to theory, methods, and tools during their education, they are not experienced engineers and may not recognize when or how to apply what they have learned to the problem at hand. Therefore, senior projects provide an opportunity for faculty to guide students through the process. This guidance does not mean that faculty is directly involved in the work, but rather provides the same guidance that their supervisor will provide when they get their first job in industry.

Project Plans Motivate Good Engineering Practice

One way in which students can be motivated to apply good engineering practice is to require that they submit a project plan that describes their team organization and individual member responsibilities, a work breakdown structure that identifies all of the activities that must be accomplished, a Critical Path Analysis and schedule that show the sequence and time that can be allotted to each activity, and an estimate of resources required. Students can also be required to submit periodic activity reports that show how they are progressing relative to the plan.

Developing a project plan is very difficult if the team has no experience on similar projects. This then provides another opportunity for faculty advisors to provide oversight to make sure that a realistic and reasonable plan is being developed. This guidance needs to be provided while the plan is being developed and can be offered by responding to questions, asking questions, or showing them how to do something.

Developing a project plan is like designing anything else. It is an iterative process that changes as new knowledge is gained. One lesson that students should learn is that the plan will change as they learn more about what it is they are doing. However, they will also learn that an initial project plan will establish project constraints that they might not be able to change. For example, they may have to live within their initial budget estimate and the project completion date will probably be fixed. How they respond to changes in their initial plan may determine the success of the overall project.

Assembly and Part Models and Drawings are Important

Students should be required to create an overall layout or assembly model of the system. This will force them to figure out how everything fits together and will greatly improve the chances for a successful project. This requires students to apply and often significantly improve their CAD skills. Students should also be required to provide a dimensioned drawing for all parts that are to be fabricated on the project. One UT Martin project required the design of an eighty-foot Eiffel Tower for the City of Paris, TN. The structure was fabricated from square steel tubing and many structural members had complex compound angles at both ends. Team members used 3D CAD software to model the structure and produce the drawings that were used by a contractor during fabrication. The contractor commented that he wished all of his projects went together as well as this one.

This requirement would have improved the probability of success for an unsuccessful robot designed by a team of electrical engineers for the IEEE robotics competition. The team members picked components out of catalogs, developed schematics for various circuits, wrote C-code for the micro controller, and started "sticking" things together. Only chalkboard sketches were prepared on how all of the components would fit together. This team used the Junk Yard Wars design approach and unfortunately was not successful. Subsequent robot design teams at UT Martin have had a more multi-disciplined team, which includes students studying mechanical as well as electrical engineering. The students studying mechanical engineering are more familiar with 3D CAD technology and are better equipped to develop the assembly and part models and drawings.

UT Martin students working on the SAE Mini-Baja competition wanted to put a transmission on their vehicle that would provide a high and low gear. After unsuccessfully searching for a commercially available transmission, they decided to design one. The design of a manual transmission that could be shifted while moving turned into quite a challenge. It also proved to be an outstanding learning opportunity. Although engineering students learn the basics of creating engineering drawings, they learn very little about how to develop tolerances. Complex drawings with tolerances were developed for all of the parts, which were fabricated by the students and local industry. The transmission was assembled with no problems and worked as designed. One of the students commented that he had no idea of the amount of detail that was required.

Analysis and Testing is Required

Students should be required to perform analyses or conduct tests to assist in the decision making process. This is what a lot of their engineering education prepares them to do. It is also this skill that often differentiates an engineer from a technician or draftsman. Although students have spent a lot of their time learning how to solve textbook analysis problems, they have little experience formulating problems on their own or even recognizing that an analysis or test should be performed. The senior projects provide an excellent opportunity for students to gain experience in formulating open-ended analysis problems. However, many students don't recognize that an analysis or test is required unless someone points it out and provides guidance on how it should be approached. This is the role of the faculty advisor.

Improving Design Competitions

There are many design competitions available to students of all majors. All of these competitions are good and provide excellent opportunities for students. However, it is the author's observation that some of the competitions promote good engineering practice while others may unwittingly promote the Junk Yard Wars design approach.

The airplane, automobile, computer, in fact all consumer products, were developed over time. In all cases the products are improved with each new release because of the engineering that was performed to optimize their performance. If the real world develops its projects over time, shouldn't the student design competitions promote this same evolutionary process? This would require that competition rules be held reasonably constant for several years, which would enable students to learn from failures in previous attempts and to develop a better and more competitive product the next time around.

Developing a product for many of the student competitions is very difficult during the nine-month academic year. During the first year of a competition, students are so overwhelmed that the Junk Yards Approach may be the only way that they can get something made for the competition. However, they learn where their weaknesses are during the competition, and can spend the next year doing more engineering to improve their design. This generally leads to more analysis, testing, and complete assembly models. The SAE Mini-Baja competition is good in this respect in that it allows students to improve their vehicle from the previous year.

On the other hand, the IEEE robotics competition tends to change the requirements for their robot each year. The author has observed that teams developing robots for this project are forced each year to cut short the engineering simply to get something ready for the competition. As a result there are a significant number of robots that don't work very well. This is because they were probably developed using the Junk Yard Wars design approach. The number of successful robots and the level of sophistication in the robots would be significantly improved if the competition were repeated over a period of two-three years.

Keeping the requirements constant also encourages the recruitment of underclassmen onto the team. Underclass students will become familiar with the competition, rules, and prior designs, which will enable them to take on a bigger leadership role when they become seniors. Underclassman participation also promotes retention because it gets students involved and lets them interact with upperclassmen. This leads to friendships and a natural mentoring, which provide encouragement and a support structure to assist underclass students who may be struggling with their coursework.

Summary

There are many similarities between the popular television shows Junk Yard Wars, Monster Garage and student projects. Students have a tendency to follow the Junk Yard Wars design approach due to the time constraints and their lack of experience in applying good engineering practice. Students can be encouraged to follow good engineering practice through adequate supervision and guidance from faculty advisors, development of project plans, development of assembly and part models and drawings, and the requirement that they perform analyses or tests to support their design. Some of the design competitions promote the application of good engineering practice by allowing students to develop their designs over several years. Design competitions that do not allow this development may be unwittingly promoting the Junk Yard Wars design approach.

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